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Choi et al.

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(54) **ROBOT USING MULTI-OUTPUT DIFFERENTIAL GEAR**

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**

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F16L 55/30 (2006.01)
F16H 48/10 (2012.01)
F16H 37/08 (2006.01)

(52) **U.S. Cl.**

CPC ***F16L 55/30*** (2013.01); *Y10S 901/25* (2013.01); *Y10T 74/20317* (2013.01); *F16H 37/08* (2013.01); ***F16H 48/10*** (2013.01)

(58) **Field of Classification Search**

USPC 475/332, 341
See application file for complete search history.

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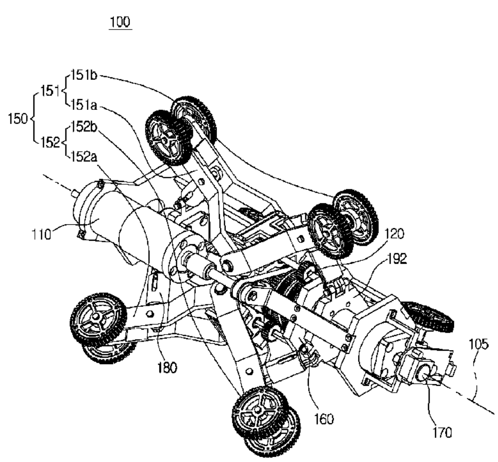
(57) **ABSTRACT**

A robot uses a multi-output differential gear to generate outputs. The robot includes a driver; a differential gear configured to receive a driving power from the driver, and to drive in an interlocked manner with the driving power to generate at least three outputs differentiated from the driving power; and a motion section configured to drive in an interlocked manner with an output generated from the differential gear, and to apply an external resistance to the differential gear.

16 Claims, 14 Drawing Sheets



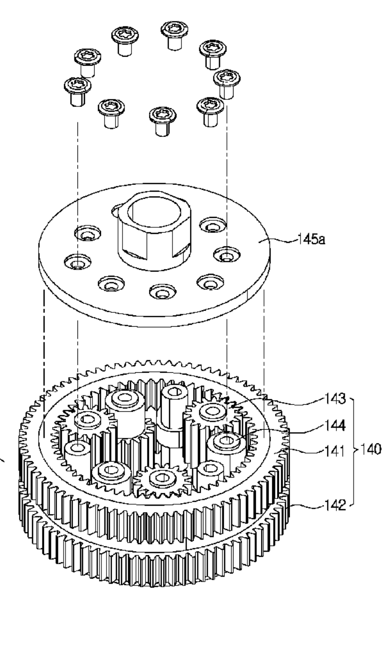


Fig. 1

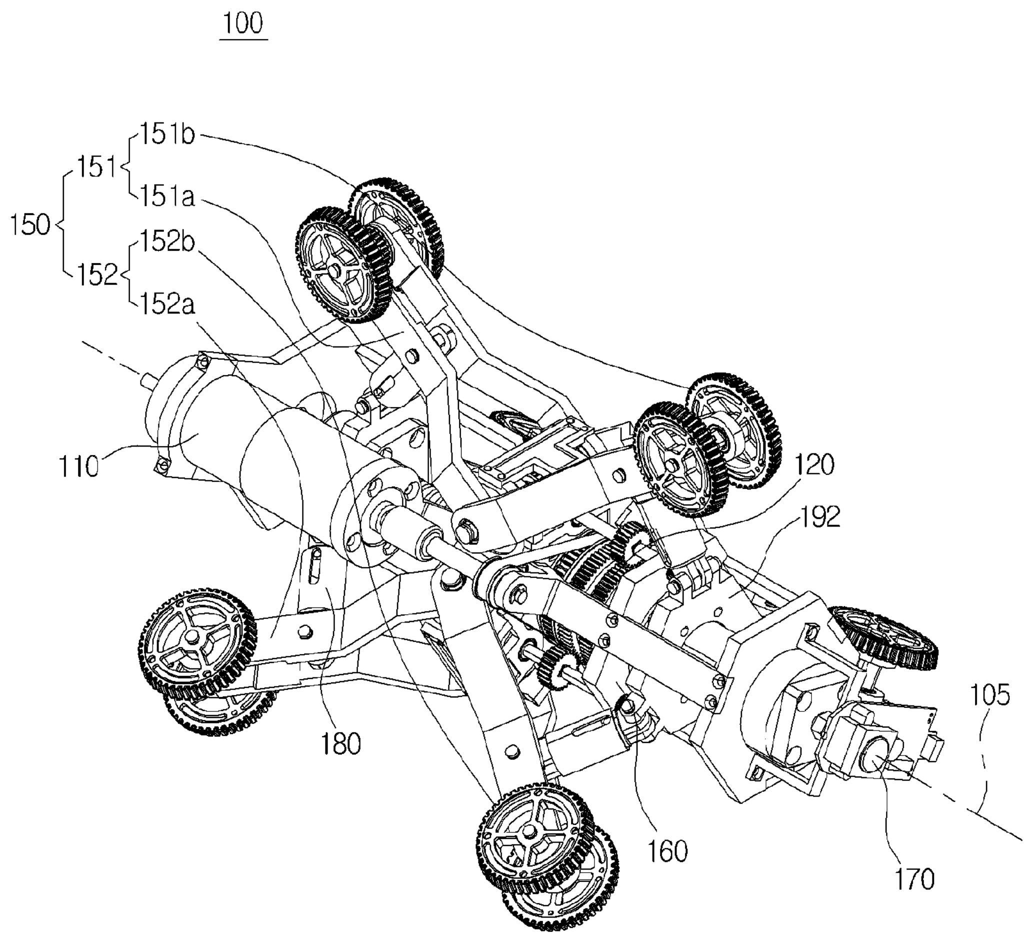


Fig. 2

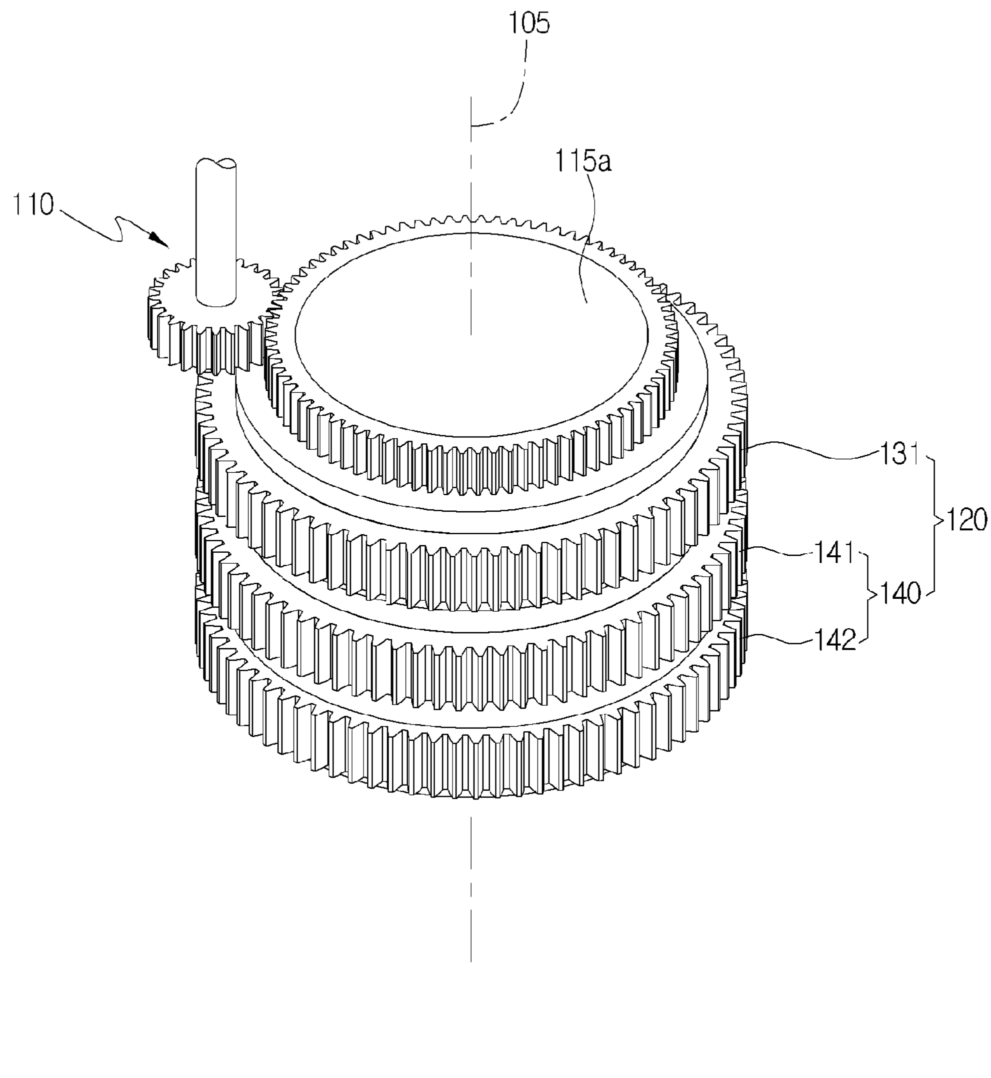


Fig. 3

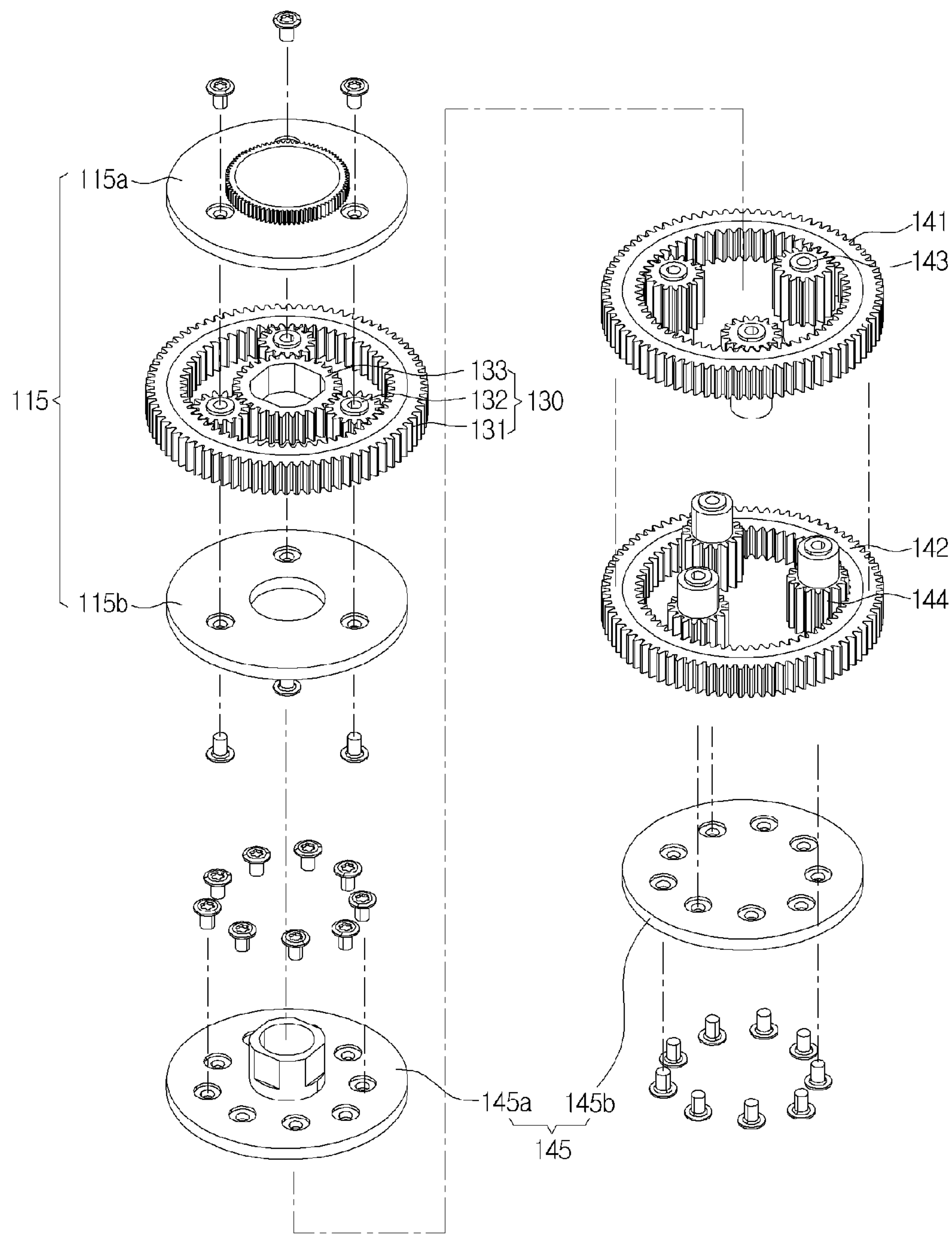


Fig. 4

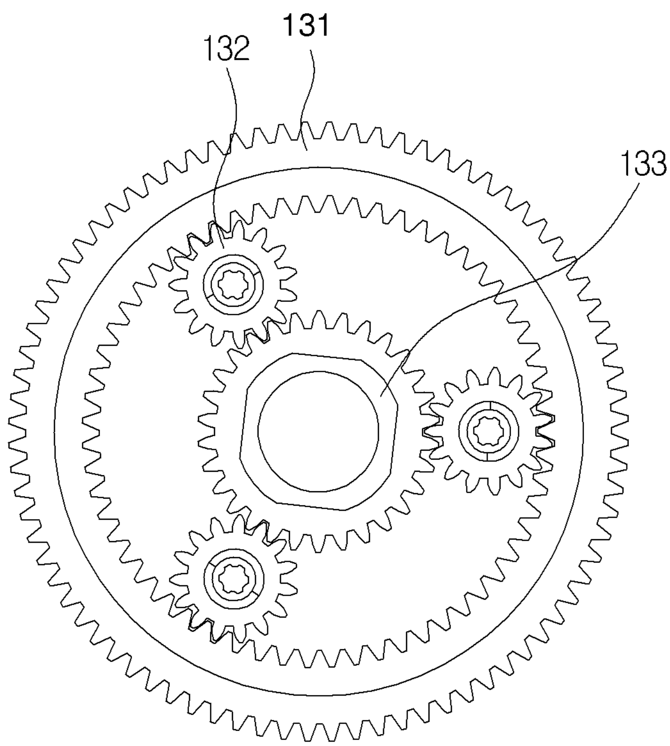


Fig. 5

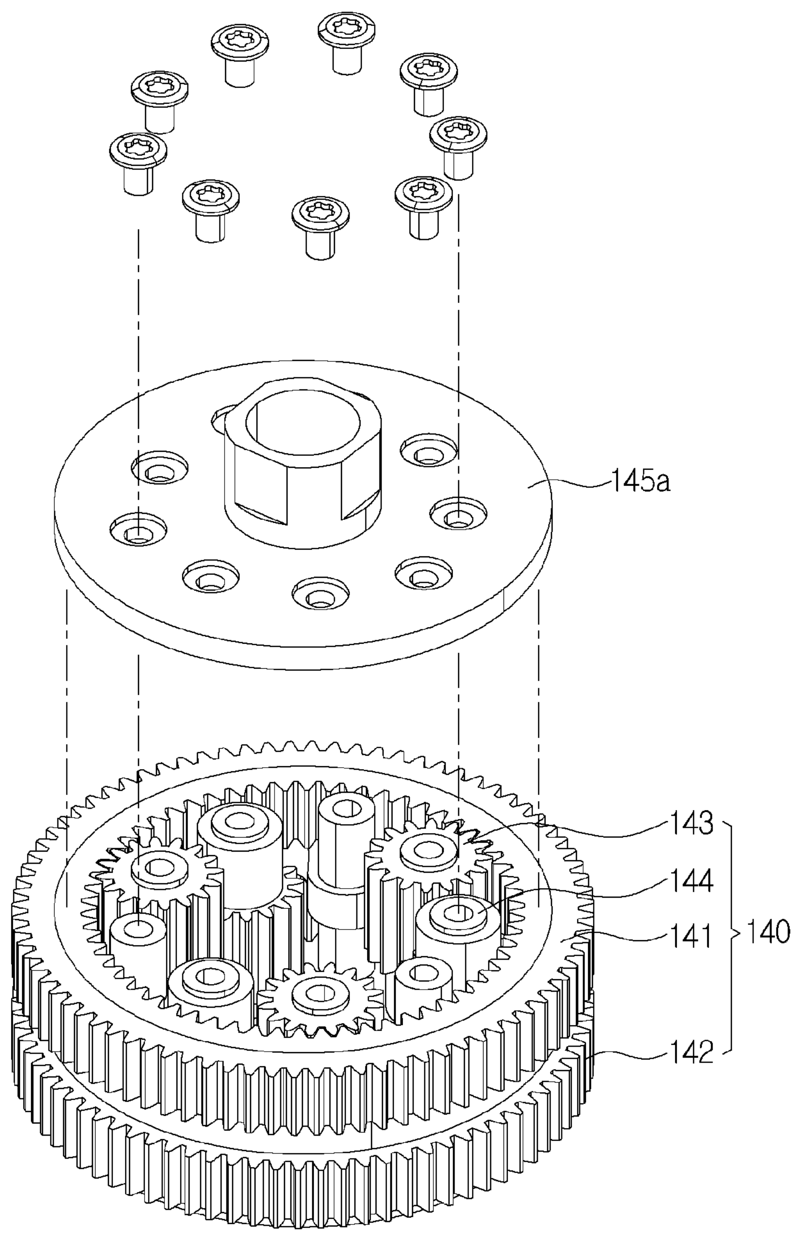


Fig. 6

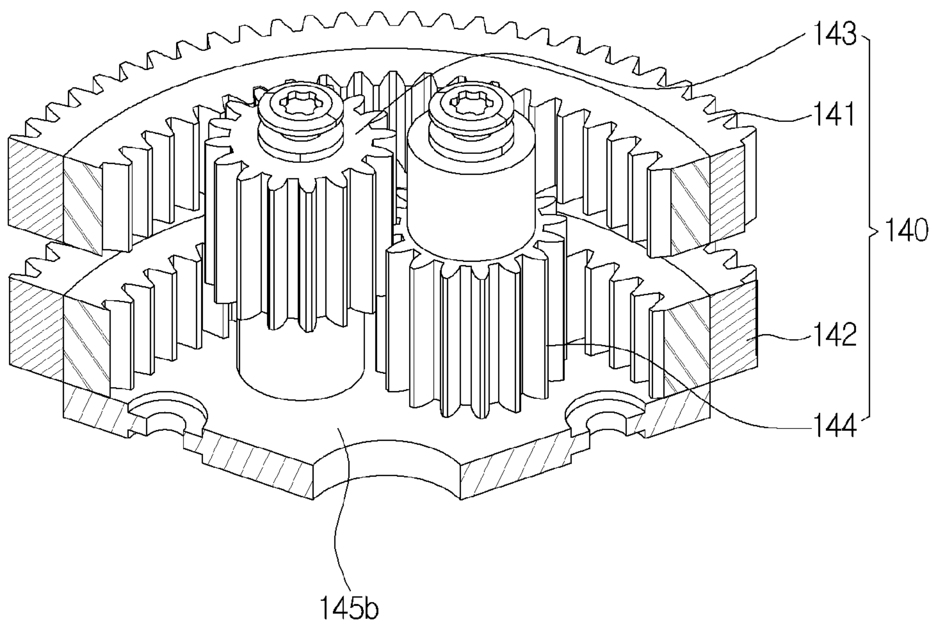
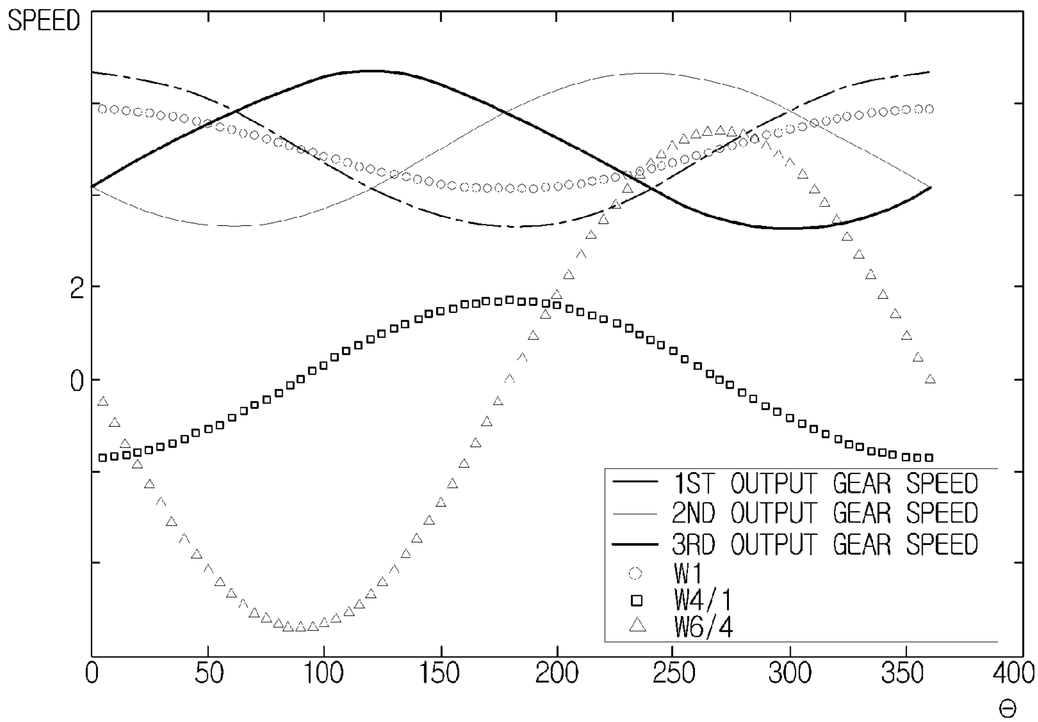


Fig. 7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1ST OUTPUT GEAR SPEED
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3RD OUTPUT GEAR SPEED
W1
W4/1
W6/4

Fig. 8

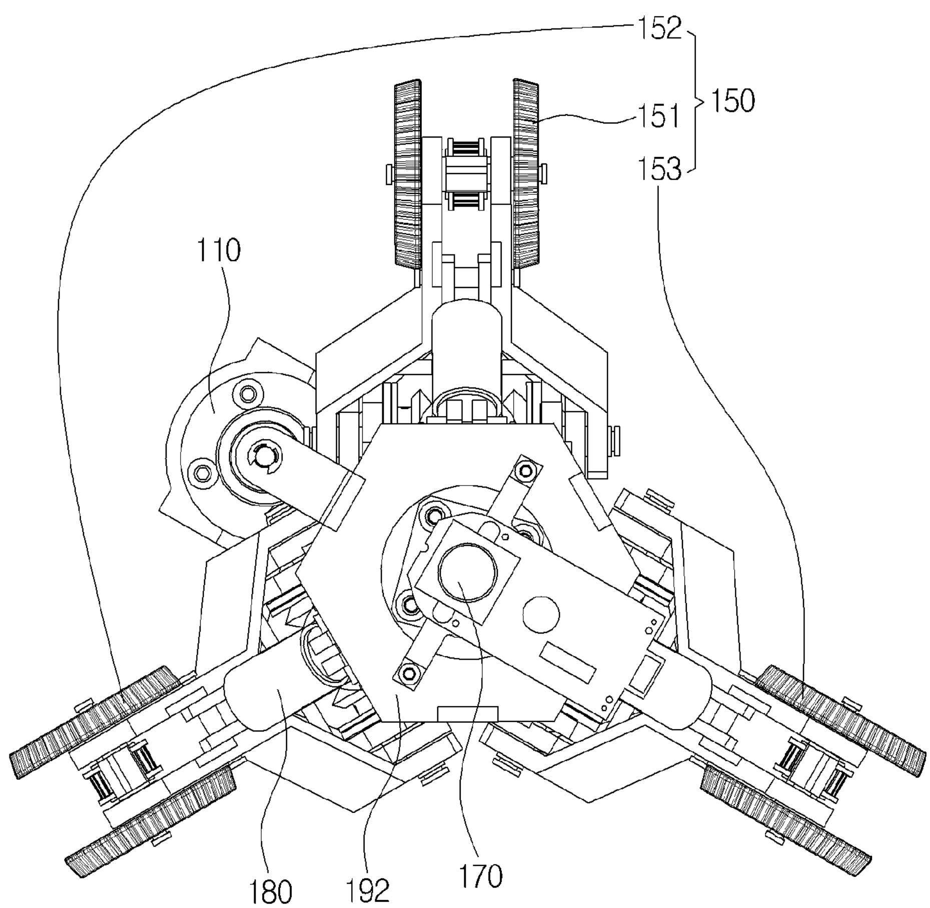


Fig. 9

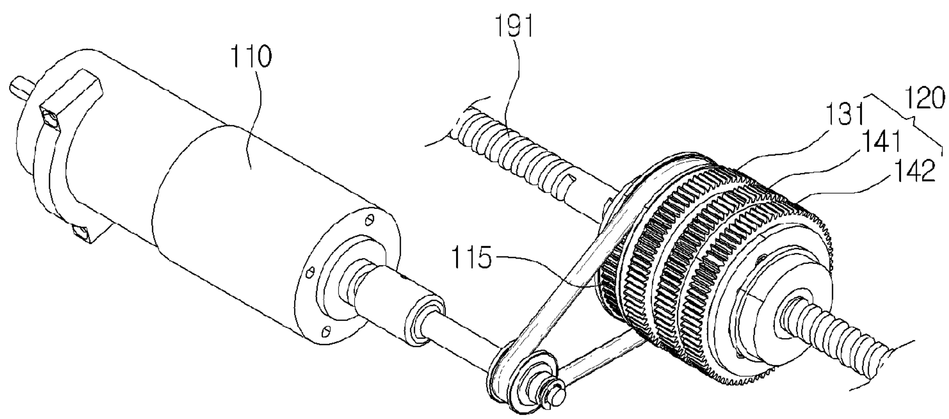
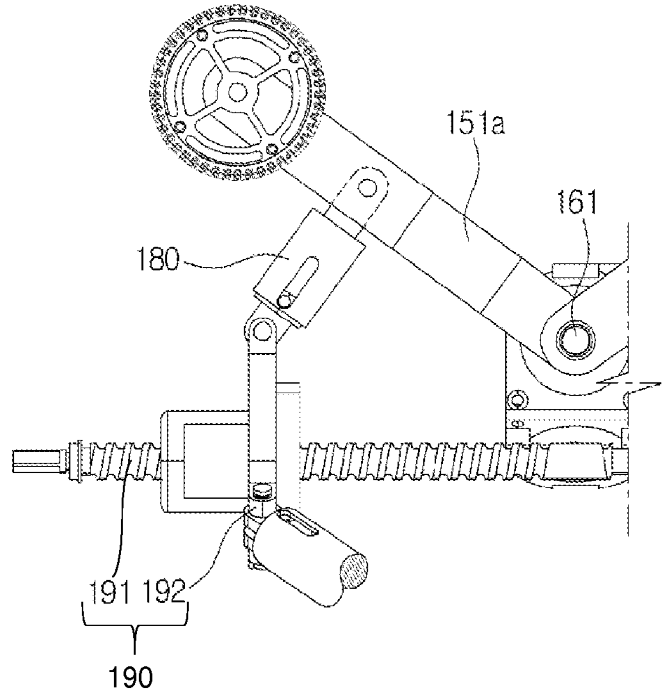
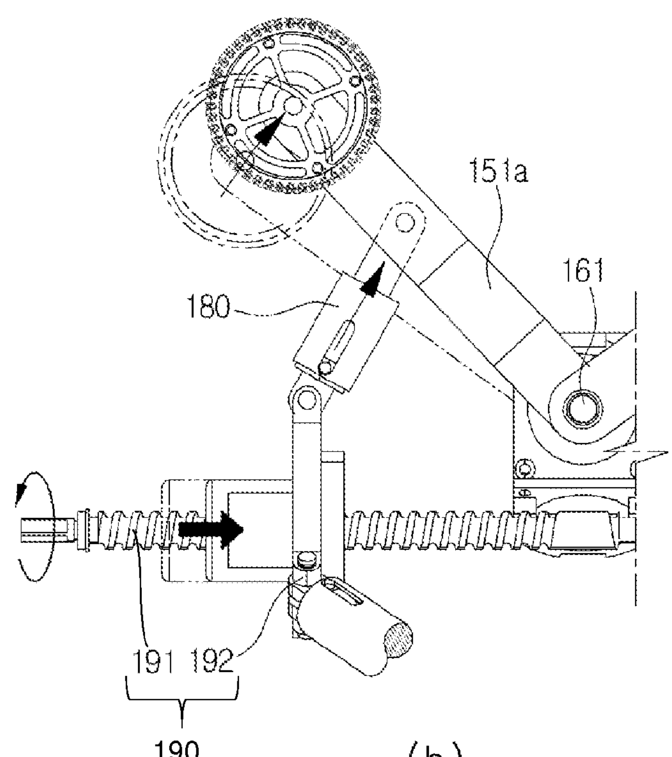


Fig. 10



(a)



(b)

Fig. 11

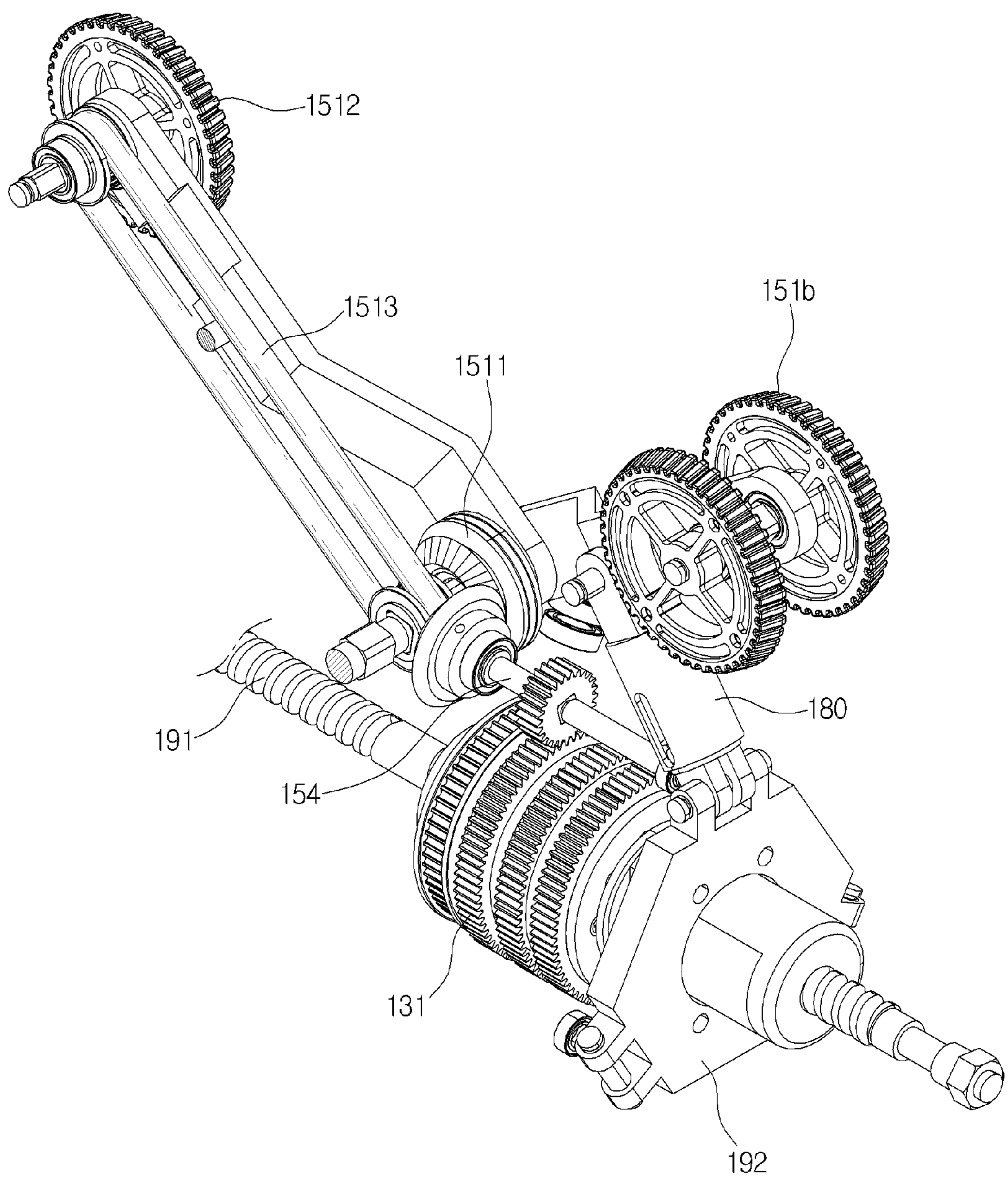


Fig. 12

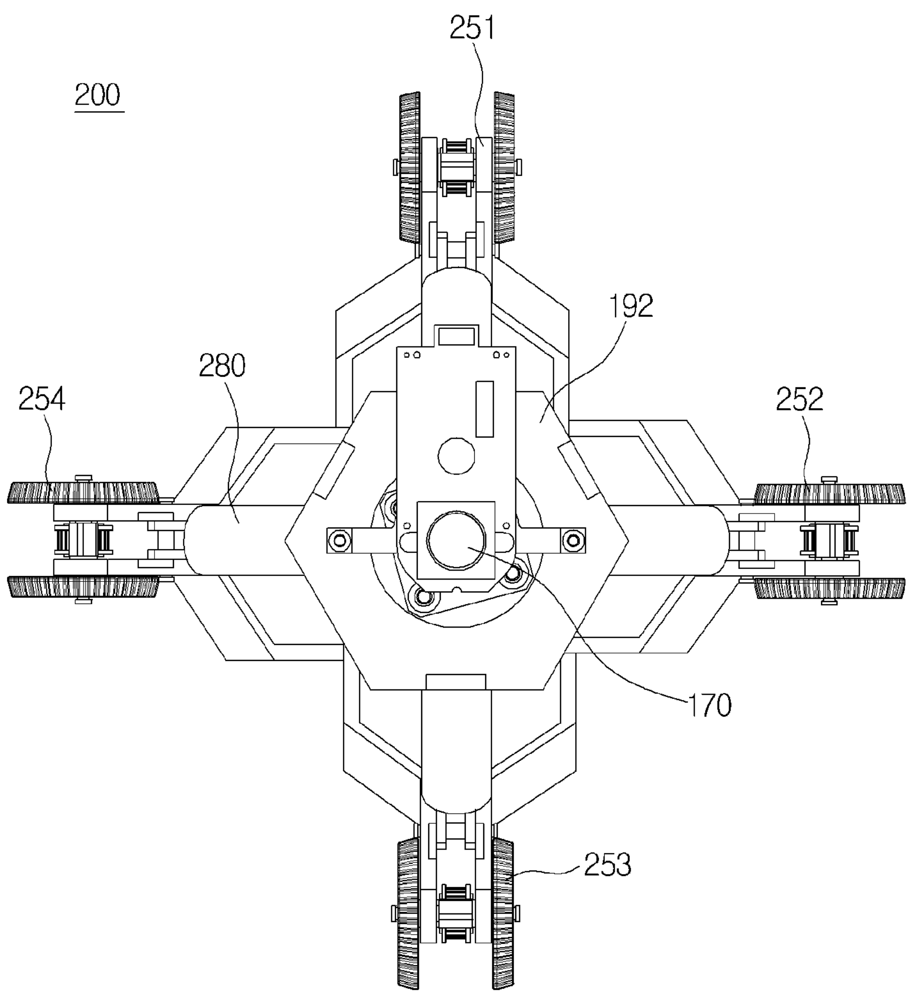


Fig. 13

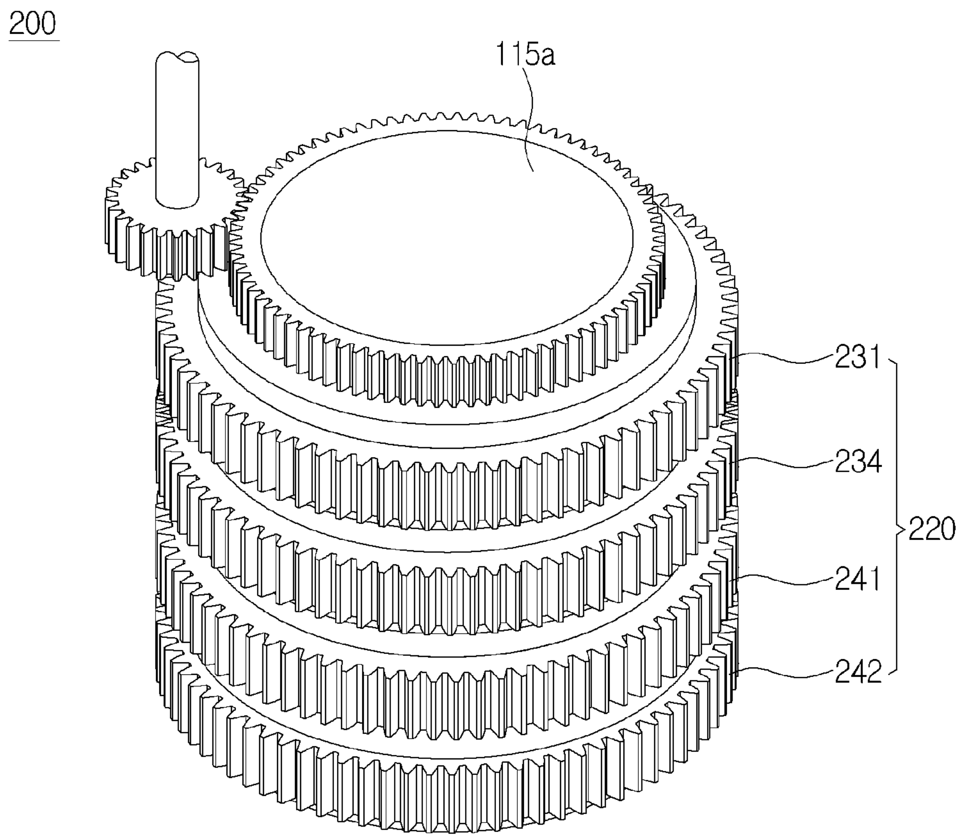
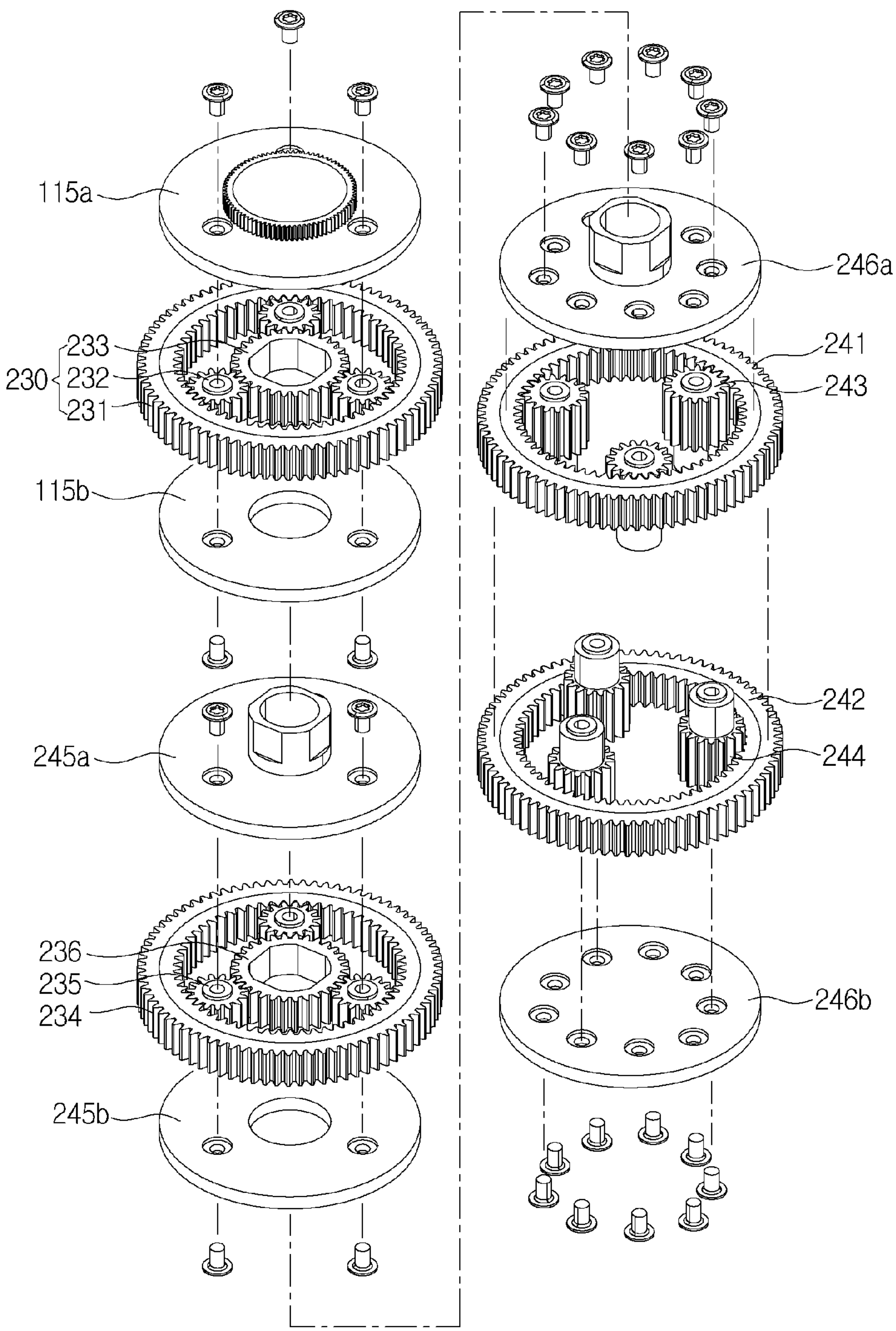


Fig. 14


115a
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115b
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245b
246a
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246b

ROBOT USING MULTI-OUTPUT DIFFERENTIAL GEAR

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of priority under 35 U.S.C. §119(a) of Korean Patent Application No. 10-2012-0119369, filed on Oct. 26, 2012, in the Korean Intellectual Property Office, the entire disclosure of which is incorporated herein by reference for all purposes.

BACKGROUND

1. Field

The following description relates to a robot using a multi-output differential gear, for example, a robot using a multi-output differential gear capable of generating a plurality of outputs using one driver and of changing each output flexibly according to changes in movement paths.

2. Description of Related Art

Plumbing facilities are one of various infrastructures in industries, and are being established as supply routes for various energy resources as they are being distributed here and there nationwide like blood vessels in a human body. However, these plumbing facilities are mostly buried underground, and thus there is much difficulty in inspecting and replacing them when the inner walls are corroded after a certain period of time or damaged by external environmental conditions.

As such, plumbing facilities are continuously wearing out, and various defects that occur in this process are causing small and large plumbing related accidents every year. However, insufficient manpower and technology makes it difficult to conduct systematic and regular inspections on the plumbing facilities.

In this regard, robots that are capable of inspecting inside the plumbing have been developed, and various researches are being conducted as well. However, conventional robots had to be equipped with a driver (actuator) for every wheel to adjust the movement state of each wheel separately according to the shape of the plumbing, thereby increasing the size of the robots.

As a result, there is a necessity for robots capable of adjusting the speed of each motion section according the shape of the plumbing using just one driver.

SUMMARY

Therefore, a purpose of the present disclosure is to resolve the aforementioned problems of prior art, that is, to provide a robot using a multi-output differential gear, the robot capable of generating a plurality of outputs through one driver and transmitting the generated outputs to each motion section.

Another purpose of the present disclosure is to provide a robot using a multi-output differential gear that can drive stably even when there are changes in movement paths.

In one general aspect, there is provided a robot using a multi-output differential gear, the robot comprising: a driver; a differential gear configured to receive a driving power from the driver, and to drive in an interlocked manner with the driving power to generate at least three outputs differentiated from the driving power; and a motion section configured to drive in an interlocked manner with an output generated from the differential gear, and to apply an external resistance to the differential gear.

In the general aspect of the robot, the differential gear may comprise: a first output gear configured to receive a driving power from the driver and to generate a first output having a different rotary speed from the driver when receiving an external resistance, and a middle gear configured to drive in an interlocked manner with the first output gear to generate a middle output; and a second differential gear configured to receive the middle output from the first differential gear and to generate a second output having a different rotary speed from the middle output when receiving an external resistance, and a third output gear configured to drive in an interlocked manner with the second output gear to generate a third output having a different rotary speed from the second output.

In the general aspect of the robot, the first output gear may be provided with sawteeth in its inner circumference, the middle gear may be provided inside of and distanced from the first output gear, and the first differential gear may further comprise a plurality of first epicyclic gears configured to engage an inner circumference of the first output gear and an outer circumference of the middle gear at the same time.

In the general aspect of the robot, the second output gear and third output gear may be provided with sawteeth in their inner circumferences, and the second differential gear may further comprise a plurality of second epicyclic gears engaging an inner circumference of the second output gear and driving in an interlocked manner with the second output gear; and a third epicyclic gear engaging an inner circumference of the second epicyclic gear and third output gear at the same time to rotate in an interlocked manner with the second epicyclic gear and third output gear.

In the general aspect of the robot, at least one of the first output gear, second output gear, and third output gear may be provided with sawteeth in its outer circumference, and the sawteeth provided in an outer circumference of at least one of the first output gear, second output gear, and third output gear may drive in an interlocked manner with the motion section to receive an external resistance.

In the general aspect of the robot, the motion section may comprise a first motion section configured to drive in an interlocked manner with the first output gear and apply an external resistance to the first output gear, a second motion section configured to drive in an interlocked manner with the second output gear and apply an external resistance to the second output gear, and a third motion section configured to drive in an interlocked manner with the third output gear and receive a third output from the second output gear.

In the general aspect of the robot, the motion section may consist of three motion sections each distanced by 120° from one another around a central axis of the differential gear.

In the general aspect of the robot, at least one of the first motion section, second motion section, and third motion section may consist of a pair of motion sections extended from an outer surface of the differential gear and distanced from each another along a longitudinal direction of the differential gear.

In the general aspect of the robot, the robot may further comprise a body section mounted to an outer surface of the differential gear to protect the differential gear.

In the general aspect of the robot, the robot may further comprise a camera module mounted to a front portion of the body section.

In the general aspect of the robot, the robot may further comprise a buffering section between the motion section and the differential gear, the buffering section configured to adjust a distance between the motion section and the differential gear so that the motion section in order to keep the motion section contacting the motion surface.

In the general aspect of the robot, the robot may further comprise a buffering adjuster interlocked with the buffering section and adjusts an initial distance between the motion section and the differential gear.

Other features and aspects may be apparent from the following detailed description, the drawings, and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view of a robot using a multi-output differential gear according a first exemplary embodiment of the present disclosure.

FIG. **2** is a schematic skewed view of a differential gear of a robot using a multi-output differential gear of FIG. **1**.

FIG. **3** is an exploded schematic skewed view of a differential gear of a robot using a multi-output differential gear.

FIG. **4** is a schematic plane view of a first differential gear of a robot using a multi-output differential gear.

FIG. **5** is an exploded schematic skewed view of a second differential gear of a robot using a multi-output differential gear.

FIG. **6** is a schematic cross-sectional view illustrating a relationship of a second differential gear of a robot using a multi-output differential gear.

FIG. **7** is an experiment graph of speeds differentiated by a differential gear in a robot using a multi-output differential gear of FIG. **1**.

FIG. **8** is a schematic plane view of a robot using a multi-output differential gear of FIG. **1**.

FIG. **9** is a schematic skewed view illustrating a relationship between a driver and a differential gear in a robot using a multi-output differential gear of FIG. **1**.

FIG. **10** is a schematic front view illustrating how an initial position of a motion section is adjusted by a buffering adjuster in a robot using a multi-output differential gear of FIG. **1**.

FIG. **11** is schematic skewed view illustrating a connection relationship between a differential gear and a motion section in a robot using a multi-output differential gear of FIG. **1**.

FIG. **12** is a schematic plane view of a robot using a multi-output differential gear according to a second exemplary embodiment of the present disclosure.

FIG. **13** is a schematic skewed view of a differential gear in a robot using a multi-output differential gear of FIG. **12**.

FIG. **14** is a schematic exploded skewed view of a differential gear in a robot using a multi-output differential gear of FIG. **12**.

Throughout the drawings and the detailed description, unless otherwise described, the same drawing reference numerals will be understood to refer to the same elements, features, and structures. The relative size and depiction of these elements may be exaggerated for clarity, illustrating, and convenience.

DETAILED DESCRIPTION

The following detailed description is provided to assist the reader in gaining a comprehensive understanding of the methods, apparatuses, and/or systems described herein. Accordingly, various changes, modifications, and equivalents of the systems, apparatuses and/or methods described herein will be suggested to those of ordinary skill in the art. Also, descriptions of well-known functions and constructions may be omitted for increased clarity and conciseness.

Hereinbelow is a detailed explanation on a robot using a multi-output differential gear according to first exemplary embodiment of the present disclosure **100** with reference to the drawings.

For convenience of explanation, the following explanation is based on an assumption that a robot using a multi-output differential gear according to a first exemplary embodiment of the present disclosure **100** is an in-pipe robot configured to move inside a pipe.

However, a robot using a multi-output differential gear according to a first exemplary embodiment of the present disclosure **100** is not limited to in-pipe robots, but may also be utilized in various ways for robots configured to enter an inner space that may not easily be entered by humans to inspect for destruction of the inner space, to transport a certain item to the inner space, or to fix the inner space etc.

FIG. **1** is a schematic skewed view of a robot using a multi-output differential gear according to a first exemplary embodiment of the present disclosure, FIG. **2** is a schematic skewed view of a differential gear of a robot using a multi-output differential gear of FIG. **1**, FIG. **3** is a schematic exploded skewed view of a differential gear of a robot using a multi-output differential gear of FIG. **1**, FIG. **4** is a schematic plane view of a first differential gear of a robot using a multi-output differential gear of FIG. **1**, FIG. **5** is an exploded schematic skewed view of a second differential gear of a robot using a multi-output differential gear of FIG. **1**, FIG. **6** is a schematic cross-sectional view of a combination relationship of a second differential gear of a robot using a multi-output differential gear of FIG. **1**, FIG. **7** is an experiment graph conducted for speeds differentiated by a differential gear in a robot using a multi-output differential gear of FIG. **1**, FIG. **8** is a schematic plane view of a robot using a multi-output differential gear of FIG. **1**, FIG. **9** is a schematic skewed view illustrating a connection relationship between a driver and a differential gear in a robot using a multi-output differential gear of FIG. **1**, FIG. **10** is a schematic front view illustrating how an initial position of a motion section is adjusted by a buffering adjuster in a robot using a multi-output differential gear of FIG. **1**, and FIG. **11** is schematic skewed view illustrating a connection relationship between a differential gear and a motion section in a robot using a multi-output differential gear of FIG. **1**.

With reference to FIGS. **1** to **11**, in a robot using a multi-output differential gear according to the first exemplary embodiment of the present disclosure **100**, each output gear of the multi-output differential gear **120** in an interlocked manner regarding one another to adjust the speed even when there exists an element that changes a movement path inside a pipe, thereby enabling stable driving. The robot **100** comprises a driver **110**, differential gear **120**, motion section **150**, body section **160**, camera module **170**, buffering section **180**, and buffering adjuster **190**.

The driver **110** applies a driving power to a robot using a multi-output differential gear according to the first exemplary embodiment of the present disclosure **100**. In this exemplary embodiment **100**, a belt is used to transmit the driving power from the driver **110** to the differential gear **120** which will be explained hereinafter, but this is not limited to a belt, but the driver **110** and the differential gear **120** may directly engage each other so that the driving power may be transmitted from the driver **110** to the differential gear **120**. Meanwhile, the driver according to the first exemplary embodiment of the present disclosure **100** is a well known technology, and thus detailed explanation thereof is omitted.

With reference to FIGS. **2** to **6**, the differential gear **120** may receive the driving power from the driver **110** and transmit the driving power to three output gears, and an external resistance applied to a motion section **150** which will be explained hereinafter may cause a differential motion to occur. A robot using a multi-output differential gear according to the first exemplary embodiment of the present disclosure **100** comprises a first differential gear **130** and a second differential gear **140**, and it is desirable that the first differential gear **130** and the second differential gear **140** have the same central axis **105**.

The first differential gear **130** transmits the driving power received from the driver **110** to the motion section **150**, and when an external resistance is applied from the motion section **150**, each gear of the first differential gear **130** drives in an interlocked manner and generates a first output having a different rotary speed from the driving power applied from the driver **110** and transmits the generated first output to the motion section **150**. In addition, a middle output having a reduced rotary speed than the driving power is transmitted from a middle gear **133** to the second differential gear **140**. The first differential gear **130** according to the first exemplary embodiment of the present disclosure comprises a first output gear **131**, three first epicyclic gears **132**, and a middle gear **133**.

Meanwhile, the first differential gear **130** may further comprise a drive transmitter **115** configured to receive the driving power from the driver **110** and transmit the driving power to the first epicyclic gear **132**. The drive transmitter **115** may comprise, but is not limited to, a spur gear provided at one end that is adjacent to the driver **110** to receive the driving power from the driver **110**.

That is, the first differential gear **130** generates a first output having a different rotary speed from the driving power at the same time of receiving the external resistance from the motion section **150**, and generates a middle output having a reduced rotary speed than the driving power. Herein, the extent of reduction of the rotary speed depends on the gear ratio of the differential gears. That is, in the case where the first output gear **131** is interlocked with the middle gear **132**, the first output that is transmitted to the middle gear **133** is equivalent to the ratio of the number of sawteeth provided in an inner circumference of the first output gear **131** to the number of sawteeth of the middle gear **133**. This will be explained in further detail hereinafter in the description about an operating method according to a first exemplary embodiment of the present disclosure.

The first output gear **131** has sawteeth in its inner circumference and outer circumference, and the sawteeth of the inner circumference engage the first epicyclic gear **132**, and the sawteeth of the outer circumference receives the external resistance and transmits a first output to a first motion section **151** that will be explained hereinafter. That is, the sawteeth of the outer circumference drive in an interlocked manner with the external resistance at same time of receiving the external resistance, to transmit the first output having a different rotary speed from the driving power to the first motion section **151**.

The first epicyclic gear **132** engages the inner circumference of the first output gear **131**, such that three of them are disposed around a central axis **105** of the first differential gear **130** at 120° from one another. The first epicyclic gear **132** transmits the first output where the external resistance received from the first output gear **131** has been considered to the middle gear **123** that will be explained hereinafter. However, the number or disposition of the first epicyclic gears **132** is not limited to the present disclosure, but may be selected when necessary.

The middle gear **133** does not rotate when there is no external resistance, whereas when an external resistance is received, the middle gear **133** drives in an interlocked manner with the first output gear **131** and transmits a middle output having a reduced rotary speed than the driving power to the second differential gear **140**.

Regarding the combination relationship of the first differential gear **130**, with reference to FIG. **4**, each of the three first epicyclic gears **132** engage the inner circumference of the first output gear **131**, and the middle gear **133** is disposed inside the first epicyclic gears **132** such that the first epicyclic gears **132** engage the outer circumference. In other words, the three first epicyclic gears **132** engage the outer circumference of the middle gear **133**, and the first output gear **131** is disposed such that the sawteeth formed in the inner circumference engage the first epicyclic gears **132**. Herein, it is desirable that the first output gear **131** has the same central axis **105** as the middle gear **133**.

As aforementioned, according to the first exemplary embodiment of the present disclosure, drive transmitters **115***a*, **115***b* may be formed between the driver **110** and the first differential gear **130**, so as to secure the position such that each of the first epicyclic gears **132** rotates individually, thereby performing a middle role so as to transmit the driving power from the driver **110** to the first epicyclic gears **132**, but this is not limited thereto.

With reference to FIG. **5**, the second differential gear **140** receives the middle output from the middle gear **133** and generates an output outside through the second output gear **141** and the third output gear **142**, and when an external resistance is received from the motion section **150**, the gears of the second differential gear **140** drive in an interlocked manner to generate a second output having a different rotary speed from the middle output and a third output having a different rotary speed than the second output through the second output gear **141** and the third output gear **142**. The second differential gear **140** according to the first exemplary embodiment of the present disclosure comprises a second output gear **141**, third output gear **142**, second epicyclic gear **143** and third epicyclic gear **144**.

When an external resistance is not received from a second motion section **152** or third motion section **153** to be explained hereinafter, the same output as the middle output is generated through each of the second output gear **141** and the third output gear **142**, and whereas when an external resistance is received from the second output gear **141** or the third output gear **142**, a second output having a different rotary speed from the middle output is generated through the second output gear **141**, and the third output gear **142** drives in an interlocked manner with the second output gear **141** to generate a third output differentiated from the second output.

Furthermore, when there is no middle output and when an external resistance is transmitted towards the second output gear **141**, the second output gear **141**, second epicyclic gear **143** and third epicyclic gear **144** drive in an interlocked manner, thereby rotating the third output gear **142** in an opposite direction to the rotating direction of the second output gear **141**.

The second output gear **141** is provided with sawteeth in its inner and outer circumferences, and the sawteeth of the inner circumference engage the second epicyclic gear **143**, and the sawteeth of the outer circumference transmit the second output to the second motion section **152**. That is, the sawteeth formed in the outer circumference of the second output gear **141** drive in an interlocked manner with the external resistance at the same time of receiving the external resistance from the second motion section **152**, transmitting the second output having a different rotary speed than the middle output to the second motion section **152**.

The third output gear **142** is provided with sawteeth in its inner and outer circumferences, and the sawteeth of the inner circumference engage the third epicyclic gear **144**, whereas the sawteeth of the outer circumference transmit the third output to the third motion section **153**. That is, the sawteeth formed in the outer circumference of the third output gear **142** drive in an interlocked manner with the external resistance at the same time of receiving the external resistance from the third motion section **153**, transmitting the third output having a different rotary speed than the driving power to the third motion section **153**.

Three second epicyclic gears **143** engage the inner circumference of the second output gear **141** and each of the third epicyclic gears **144**, such that they are arranged at 120° from one another around the central axis **105** of the second differential gear **140**. The second epicyclic gears **143** transmit the external resistance received from the second output gear **141** to the third epicyclic gears **144** to be explained hereinafter. However, the number and arrangement of the second epicyclic gears **143** are not limited to the present disclosure, but may obviously be selected when necessary.

The three third epicyclic gears **144** engage the inner circumference of the third output gear **142** and the second epicyclic gear **143**, such that they are arranged at 120° from one another around the central axis **105** of the second differential gear **140**. The third epicyclic gear **144** transmits the external resistance received from the third output gear **142** to the second epicyclic gear **143**. Meanwhile, it is desirable that the number and arrangement of the third epicyclic gears **144** are selected in accordance with the second epicyclic gears **143**.

An external resistance may be received from the second motion section **152** and the third motion section **153** at the same time, in which case the second output gear **141**, third output gear **142**, second epicyclic gear **143** and third epicyclic gear **144** drive in an interlocked manner to one another, and this can be regarded as the external resistances received from the second motion section **152** and the third motion section **153** as being offset or reinforced by one another, which is the same as the external resistance being received in one of the second motion section **152** and third motion section **153**.

As illustrated in FIG. **5** or FIG. **6**, regarding the combination relationship of the second differential gear **140**, the sawteeth formed in the inner circumference of the second output gears **141** engage the second epicyclic gears **143** each of which engages its corresponding third epicyclic gear **144**. Furthermore, the third epicyclic gears **144** engage the sawteeth formed in the inner circumference of the third output gear **142**. However, since only a portion of the second epicyclic gear **143** and a portion of the third epicyclic gear **144** engage each other, it does not mean that the second epicyclic gear **143** and the third output gear **142** directly engage each other or that the third epicyclic gear **144** and the second output gear **141** directly engage each other. However, even by this combination, it is desirable that the second output gear **141** and the third output gear **142** are disposed such that they are distanced from each other.

Meanwhile, according to the first exemplary embodiment of the present disclosure **100**, it is desirable that a middle output transmitter **145***a*, **145***b* is formed between the first differential gear **130** and the second differential gear **140**. The middle output transmitter **145***a*, **145***b* is connected to the middle gear **133** and secures the position of the second epicyclic gears **143** and third epicyclic gears **144** such that each of them may rotate separately from one another, and, when a middle output is generated, performs a role of transmitting the middle output to the second epicyclic gear **143**.

The motion section **150** drives in an interlocked manner with the output gears, and rotates as it receives the output from the output gears, and receives the external resistance generated during the movement and transmits the generated external resistance to each output gear. The motion section

150 according to the first exemplary embodiment of the present disclosure comprises a first motion section **151**, a second motion section **152**, and a third motion section **153**.

With reference to FIG. **11**, the first motion section **151** rotates as it receives a driving power or a first output from the first output gear **131**, and when a cause for external resistance such as that there is formed a motion section in a movement path inside the pipe, transmits the external resistance to the first output gear **131**.

According to the first exemplary embodiment of the present disclosure **100**, the first motion section **151** consists of a pair of wheels so as to support both ends of the robot **100**, one of which **151***a* is extended from a first intersection **161** of the body section **160** that will be explained hereinafter and is disposed obliquely towards the front of the differential gear, and the other **151***b* disposed obliquely towards the rear of the differential gear.

Meanwhile, by way of example, the first motion section **151** according to the first exemplary embodiment of the present disclosure **100** may comprise a first output direction converter **1511**, a first wheel **1512**, and a first belt **1513**. The first output direction converter **1511** may comprise two bevel gears disposed at the body section **160** such that they face each other at a first intersection **161** where two first motion sections **151** intersect and engage the bevel gear of the first output transmitting gear **154**, and a spur gear disposed between the two bevel gears to rotate together with the bevel gears. The first wheel **1512** may comprise a spur wheel provided between the two wheels facing each other so as to rotate together with the two wheels. The first belt **1513** connects the spur gear of the first out direction converter **1511** and the spur gear of the first wheel **1513** so that the two spur gears can drive in an interlocked manner.

The first output gear **131** engages the spur of the first output transmitting gear **1511**, and the bevel gear of the first output transmitting gear **1511** is extended up to the first intersection and engages the bevel gear of the first output direction converter **1512**.

Furthermore, the spur gear of the first output direction converter **1512** and the spur gear of the first wheel **1513** are connected to each other by the first belt **1514** so as to drive in an interlocked manner.

However, such a configuration is an example of a structure configured such that an output is transmitted from the differential gear **120** to the motion sector **150** according to the first exemplary embodiment of the present disclosure **100**, and thus there is no limitation thereto.

Meanwhile, an operating method of the first motion section **151** will be explained in detail in the description on the first exemplary embodiment of the present disclosure **100** that will be explained hereinafter, and thus further detail is omitted.

The second motion section **152** and the third motion section **153** have the same configuration as the first motion section **151**, and thus explanation on further detail is omitted, except that the second motion section **152** receives the second output and transmits the external resistance through the second output gear **141**, and the third motion section **153** receives the third output and transmits the external resistance through the third output gear **142**.

Furthermore, the first motion section **151**, second motion section **152** and third motion section **153** according to the first exemplary embodiment of the present disclosure **100** are distanced by 120° from one another around the central axis of differential gear **120**, the motion sections **151***a*, **152***a*, **153***a* are disposed in the front **105** of the differential gear **120** on the same concentric circle, and the motion sections **151***b*, **152***b*, **153***b* are disposed in the rear of the differential gear **120** are on the same concentric circle.

Furthermore, it is desirable that the diameter of the concentric circle formed by the motion sections **151***a*, **152***a*, **153***a* disposed in the front of the differential gear **120** is identical as the diameter of the concentric circle formed by the motion sections **151***b*, **152***b*, **153***b* disposed in the rear of the differential gear **120**.

However, there is no limitation to the aforementioned disposition, and thus the disposition may be changed according to the user's intentions.

With reference to FIG. **8**, the body section **160** is mounted to the outer surface of the differential gear **120** to protect and support the differential gear **120**. That is, the body section **160** is provided with the differential gear **120** in its inside and a motion section **150** in its outside so as to enable an efficient process of transmitting an output from the differential gear **120** to the motion section **150** or from the motion section **150** to the differential gear **120**.

With reference FIG. **8**, the camera module **170** is provided in the front of the body section **160** to photograph an environment of the movement path of the robot. That is, the camera module **170** informs the user whether the path inside the pipe is a bent or straight etc.

With reference to FIG. **8** or FIG. **10**, the buffering section **180** is connected to the motion section **150**, and adjusts the distance between the motion section **150** and the differential gear **120** so as to keep the motion section **150** in contact with the inner wall of the pipe. According to the first exemplary embodiment of the present disclosure **100**, the buffering section **180** adjusts the distance between the motion section **150** and the differential gear **120** according to changes of the movement path inside the pipe by adjusting the angle between the motion section **150** and the central axis **105** of the differential gear **120**, but there is no limitation thereto.

That is, in the case where inside of the pipe is straight, the motion section **150** and the inside wall of the pipe can be kept contacting each other without having to adjust the distance between the motion section **150** and the differential gear **120**. However, when inside the pipe is bent, the distance between the motion section **150** and the differential gear **120** has to be adjusted in order to keep the motion section **150** and the inner wall of the pipe contacting each other. According to the first exemplary embodiment of the present disclosure **100**, the buffering section **180** is, but is not limited to, a spring damper.

With reference to FIG. **10**, the buffering adjuster **190** adjusts the buffering section **180** to adjust the initial distance between the motion section **150** and the differential gear **120**. According to the first exemplary embodiment of the present disclosure **100**, the buffering adjuster **190** may comprise a ball screw **191** provided along the central axis **105** of the differential gear **120** and a buffering connector **192** configured to move along the ball screw **191** and connected to one side of the buffering section **180**, and adjusts the position of the buffering connector **192** along the ball screw **191** so as to adjust the initial distance between the motion section **150** and the differential gear **120**.

Regarding the combination relationship between the motion section, buffering section **180** and buffering adjuster **190** according to the first exemplary embodiment of the present disclosure **100**, a buffering adjuster **190** is disposed inside the body section **160** around the central axis **105** of the differential gear **120**, and each buffering section **180** is combined with the buffering connector **192** at its one end, the other end being connected to the first motion section **151**, second motion section **152**, and third motion section **153**. In the buffering adjuster **190**, when the buffering connector **192** moves along the ball screw **191**, the angle of the first motion section **151**, second motion section **152**, and third motion section **153** connected to the buffering section **180** and the central axis of the differential gear **120** either increases or decreases. That is, the length of the motion section **150** is constant, but the angle between the motion section and the central axis **105** changes, thereby changing the distance between the differential gear **120** and the motion section **150**.

In addition, it is possible to adjust the number of the buffering adjuster **190** according to the number of the motion sections **150** that drive in an interlocked manner with the buffering adjuster **190**, but it is desirable to have one buffering adjuster **190** considering the size of the robot.

However, the buffering adjuster **190** is not limited to such a buffering adjuster **190** explained in the first exemplary embodiment of the present disclosure **100**, but may obviously be formed differently depending on the user's intentions.

Hereinbelow is explanation on an operation of a robot using such a multi-output differential gear mentioned above according to a first exemplary embodiment **100**.

First of all, hereinbelow is explanation on an operation of the differential gear **120**, where a driving power and external resistance is received, a differentiation is made, and the differentiated output value is transmitted to the motion section **150**.

First of all, hereinbelow is explanation on an operation of the first differential gear **130**. In the case where an external resistance is not transmitted from the first motion section **151** to the first output gear **131**, the driving power transmitted from the driver **110** is transmitted to the first epicyclic gear **132** by the drive transmitter **115***a*, **115***b*, and the first epicyclic gear **132** rotates the first output gear **131** in the same rotation direction as that of the driver **110** as it rotates along the outer circumference of the middle gear **133**. Herein, the rotary speed depends on the ratio of the number of sawteeth of the first output gear **131** and the number of sawteeth of the first epicyclic gear **132**.

In this case, the middle gear **133** is at a still state, and thus the middle output value is 0. The second differential gear **140** also falls at a still state if there is no external resistance received.

However, when an external resistance is transmitted to the first output gear **131**, the first output gear **131** generates a first output having a rotary speed different from the rotary speed of the external power, and the gears of the first differential gear **130** drive in an interlocked manner, generating a middle output in the middle gear **133**. Accordingly, the middle gear **133** performs the function of differentiation regarding the external power.

Meanwhile, regarding an operation method of the second differential gear **140**, if the middle output transmitted to the second differential gear **140** is 0, the second output and third output by the second output gear **141** and the third output gear **142** are affected by whether or not an external resistance is transmitted. When there is no external resistance received, a middle output is not transmitted to the second differential gear **140**, and thus neither a second output or third output is generated, but when an external resistance is transmitted to the second output gear **141** or the third output gear **142**, the second output gear **141** and third output gear **142** would rotate in an interlocked manner, generating a second output and a third output.

Herein, if a middle output is transmitted to the second differential gear **140** and an external resistance is transmitted to the second output gear **141**, the second output gear **141** would generate a second output having a rotary speed different from that of the middle output, and the third output gear **142** that drives in an interlocked manner with the second output gear **141** would generate a third output having a rotary speed different from that of the second output.

On the other hand, even when an external resistance is transmitted to the third output gear **142**, the third output gear **142** would perform the same operations as in the case where an external resistance is transmitted to the second output gear. And when an external resistance is transmitted to both the second output gear **141** and the third output gear **142**, the external resistance would be offset or reinforced, and thus the second output gear and third output gear would operate in the same manner as in the case where an external resistance is transmitted to only one of the second output gear **141** and third output gear **142**. That is, both the second output gear **141** and the third output gear **142** perform the function of differentiation.

The first output gear **131**, second output gear **141**, and third output gear **142** may have different rotary speed depending on the number of sawteeth of the gears that are interlocked, but may rotate in the same rotation direction. If the three output gears must rotate in the same direction at the same speed, the relative speed of the gears inside would be 0, but if each of the three output gears must rotate at a different speed from one another, that is, if the output gears perform the function of differentiation, the relative speed of each output gear would differ from one another. This could be explained by the mathematical formula below.

$$1.\ \begin{bmatrix} \omega_1 \\ \omega_{4/1} \\ \omega_{6/4} \end{bmatrix} = \begin{bmatrix} 1\left(\frac{n_3}{n_2}\right) & \left(-\frac{n_4}{n_3}\right) & 0 \\ 1 & 1 & \frac{n_6}{n_5} \\ 1 & 1 & -\left(\frac{n_6}{n_8}\right) \end{bmatrix}^{-1} \begin{bmatrix} \omega_2 \\ \omega_5 \\ \omega_8 \end{bmatrix}.$$

Herein, ω_1 represents the rotary speed of the driving power transmitted from the driver **110**, ω_2 represents the rotary speed of the first output gear **131**, ω_5 represents the rotary speed of the second output gear **141**, ω_8 represents the rotary speed of the third output gear **142**, $\omega_{4/1}$ represents the relative speed of the middle gear **133** to the driving power, and $\omega_{6/4}$ represents the relative speed of the second epicyclic gear **143** to the middle gear **133**. Furthermore, n_3 represents the number of sawteeth of the first output gear **131**, n_4 represents the number sawteeth of the middle gear **133**, and n_3 represents the number of sawteeth of the first epicyclic gear **132**. Furthermore, n_6 represents the number of sawteeth of the second epicyclic gear **143**, n_5 represents the number of sawteeth of the second output gear **141**, n_7 represents the number of sawteeth of the third epicyclic gear **144**, and n_8 represents the number of sawteeth of the third output gear **142**.

First of all, the speed of the first output gear, ω_2, the speed of the second output gear, ω_5, and the speed of the third output gear, ω_8, are shown in lines, while the rotary speed of the external power, ω_1, the relative speed of the middle gear to the external power, $\omega_{4/1}$, and the relative speed of the second epicyclic gear to the middle gear, $\omega_{6/4}$, are shown in dots that are connected. With reference to FIG. **7**, it can be seen that differentiations are made as the relative speeds of the gears change according to θ.

Hereinafter is explanation on an operation of a robot using a multi-output differential gear according to an exemplary embodiment of the present disclosure based on the operation of the aforementioned differential gear **120**.

First of all, when the path inside the pipe is straight, it can be assumed that there is no external resistance, and thus a first output of the same size of the driving power is transmitted from the first output gear **131** to the first motion section **151**. Herein, since a second and third output are not generated from the second output gear **141** and third output gear **142**, the second motion section **152** and third motion section **153** rotate at the same rotating speed as the first motion section.

Next, when the path inside the pipe is bent or has an obstacle and an external resistance is generated, the external resistance is transmitted from at least one of the first motion section **151**, second motion section **152**, and third motion section **153**, and the rotary speed of each motion section **150** will differ according to the operation of the aforementioned differential gear **120**.

Regarding the operation of the motion section **150** based on the case of the first motion section **151** according to a first exemplary embodiment of the present disclosure **100**, with reference to FIG. **11**, when the first output gear **131** rotates as it receives a driving power from the driver **110**, the spur gear of the first output transmitting gear **154** rotates together with the first output gear **131**, thereby rotating the bevel gear of the first output transmitting gear **154**. Accordingly, the two bevel gears and the spur gear of the first output direction converter **1511** provided in the first intersection **161** rotate, and the spur gear of the first output direction transmitter **511** and the spur gear of the first wheel **1512** connected by the first belt **1513** also rotate together. And thus, the wheels of the first wheel **1512** rotate as well.

In addition, such an operation is made in the same manner in the second motion section **152** and third motion section **153** as well.

Meanwhile, with reference to FIG. **10**, due to the curve inside the pipe, inertia is applied to the robot **100**, and to correct this, the buffering section **180** operates individually. That is, when an inertia is applied to the robot **100** in the direction in which a centrifugal force is applied, the pipe wall in the subject direction and the robot **100** become close to each other, and thus the buffering section **180** connected to the motion section is compressed and compensates for the distance, and the buffering section **180** connected to the motion section formed in the opposite direction is loosened and compensates for the distance, thereby keeping the robot **100** and the inner wall of the pipe contacting each other even in such a bent pipe.

Furthermore, it is possible to adjust the buffering adjuster **190** in accordance with the inner diameter of the pipe to adjust the distance between the differential gear **120** and the motion section **130**, so that the diameter of the concentric circle formed from each motion section **150** is at least the inner diameter of the pipe.

Next, hereinafter is explanation on a robot using a multi-output differential gear according to a second exemplary embodiment of the present disclosure.

FIG. **12** is a schematic plane view of a robot using a multi-output differential gear according to an second exemplary embodiment of the present disclosure, FIG. **13** is a schematic skewed view of a differential gear in a robot using a multi-output differential gear of FIG. **12**, and FIG. **14** is an exploded schematic skewed view of a differential gear in a robot using a multi-output differential gear of FIG. **12**.

With reference to FIGS. **12** to **14**, a robot using a multi-output differential gear according to a second exemplary embodiment of the present disclosure **200** comprises a driver **110**, differential gear **220**, motion section **250**, body section **160**, camera module **170**, buffering section **280**, and buffering adjuster **190**.

The driver **110**, body section **160**, camera module **170**, and buffering adjuster **190** are identical to those of the first exemplary embodiment of the present disclosure **100**, and thus detailed explanation thereof is omitted.

The first differential gear **230** comprises a first output gear **231**, three epicyclic gears **232**, a first middle gear **233**, a fourth output gear **234**, three fourth epicyclic gears **235**, and a second middle gear **236**. Furthermore, there may be provided, but is not limited to, a first middle output transmitter **245***a*, **245***b* between the first middle gear **233** and the fourth epicyclic gear **234** to transmit the first middle output to the fourth epicyclic gear **235**.

Furthermore, there may be provided, but is not limited to, a second middle output transmitter **246***a*, **246***b* between the second middle gear **236** and the second epicyclic gear **143** to transmit the second middle output from the second middle gear **236** to the second epicyclic gear **143**.

Regarding the disposition of the first differential gear **230**, the first differential gear **230** according to the second exemplary embodiment **200** comprises two first differential gears **130** of the first exemplary embodiment **100** disposed adjacently to each other. That is, in the second exemplary embodiment **200**, a third differential gear having the same configuration as the first differential gear **130** is disposed between the first differential gear **130** and the second differential gear **140** of the first exemplary embodiment **100**.

The motion section **250** drives in an interlocked manner with the first output gear **231**, second output gear **141**, third output gear **142**, and fourth output gear **234**. They rotate as they receive outputs from each of the output gears, and then receive the external resistance generated by the rotation and transmit the same to each of the output gears. The motion section **250** according to the second exemplary embodiment of the present disclosure **200** comprises a first motion section **251**, second motion section **252**, third motion section **253**, and fourth motion section **254**.

According to the second exemplary embodiment **200** of the present disclosure, the four motion sections **251**, **252**, **253**, **254** are disposed, but are not limited to, such that each of them is distanced by 90° from one another around the central axis **105** of the differential gear **220**. Meanwhile, regarding the motion sections, everything is the same as in each motion section **150** of the first exemplary embodiment besides the disposition relationship, and thus further detailed explanation is omitted.

There are provided four buffering sections **280** so as to correspond to the four motion sections, but beside this, everything regarding the buffering section is the same as in the first exemplary embodiment **100**, and thus further detailed explanation is omitted

Regarding the overall shape of a robot using a multi-output differential gear, compared to the first exemplary embodiment **100**, in the second exemplary embodiment **200**, the differential gear **220** has four output gears, and thus there are provided four motion sections **250** and four buffering sections **280** so as to correspond thereto.

Of course, the first differential gear **230** may comprise three or more output gears, additional epicyclic gears and middle gears, and additional motion sections and buffering sections corresponding thereto.

Hereinbelow is explanation on an operation method of a robot using a multi-output differential gear according to the second exemplary embodiment of the present disclosure **100**.

The operation method of the second differential gear **240** is the same as in the first exemplary embodiment **100**, except that the number of elements of the motion sections and buffering sections **280** increased.

Hereinafter is explanation on the operation of the first differential gear **230**. The process of generating a driving power and a first middle output from the driver **110** to the first middle gear **233** is the same as in the first exemplary embodiment **100**.

First, when a first middle output is generated from the first middle gear **223**, it is transmitted to the fourth epicyclic gear **235** that drives in an interlocked manner with the first middle gear **223** by the second middle output transmitter. The first middle output transmitted to the fourth epicyclic gear **235** is converted into a second middle output in the second middle gear **236** depending on whether or not an external resistance is transmitted from the fourth output gear **234** as the fourth epicyclic gear **235**, fourth output gear **234**, and second middle gear **236** drive in an interlocked manner.

When an external resistance is transmitted to the fourth output gear **234**, and a second middle output is generated from the second middle gear **236**, such a second middle output is transmitted to the second differential gear **240**, driving the second differential gear **240**. The operation of the second differential gear **240** thereafter is the same as in the first exemplary embodiment **100**, and thus further detailed explanation is omitted.

A number of examples have been described above. Nevertheless, it will be understood that various modifications may be made. For example, suitable results may be achieved if the described techniques are performed in a different order and/or if components in a described system, architecture, device, or circuit are combined in a different manner and/or replaced or supplemented by other components or their equivalents. Accordingly, other implementations are within the scope of the following claims.

DESCRIPTION OF REFERENCE NUMERALS

- **100**: ROBOT USING MULTI-OUTPUT DIFFERENTIAL GEAR ACCORDING TO FIRST EXEMPLARY EMBODIMENT
- **110**: DRIVER
- **120**: DIFFERENTIAL GEAR
- **130**: FIRST DIFFERENTIAL GEAR
- **140**: SECOND DIFFERENTIAL GEAR
- **150**: MOTION SECTION
- **160**: BODY SECTION
- **170**: CAMERA MODULE
- **180**: BUFFERING SECTION
- **190**: BUFFERING ADJUSTER
- **200**: ROBOT USING MULTI-OUTPUT DIFFERENTIAL GEAR ACCORDING TO SECOND EXEMPLARY EMBODIMENT
- **220**: DIFFERENTIAL GEAR
- **230**: FIRST DIFFERENTIAL GEAR
- **240**: SECOND DIFFERENTIAL GEAR
- **250**: MOTION SECTION
- **260**: BODY SECTION
- **280**: BUFFERING SECTION
- **290**: BUFFERING ADJUSTER

What is claimed is:

1. A robot using a multi-output differential gear, the robot comprising:

a driver;

a differential gear assembly configured to receive a driving power from the driver, receive at least one external resistance, and drive in an interlocked manner with the driving power to generate a plurality of outputs differentiated from the driving power, the differential gear assembly comprising:

a first differential gear set configured to receive the driving power from the driver and comprising

a first output gear configured to generate a first output among the plurality of outputs having a different rotary speed from the driver when receiving a first external resistance among the at least one external resistance,

a middle gear configured to drive in an interlocked manner with the first output gear to generate a middle output among the plurality of outputs, and

a second differential gear set configured to receive the middle output from the first differential gear set and comprising

a second output gear configured to generate a second output among the plurality of outputs having a different rotary speed from the middle output when receiving a second external resistance among the at least one external resistance, the second output gear comprising sawteeth in its inner circumference,

a plurality of second epicyclic gears engaging the inner circumference of the second output gear and driving in an interlocked manner with the second output gear,

a third output gear configured to drive in an interlocked manner with the second output gear to generate a third output among the plurality of outputs having a different rotary speed from the second output, the third output gear comprising sawteeth in its inner circumference, and

a third epicyclic gear engaging the second epicyclic gear and an inner circumference of the third output gear at the same time to rotate in an interlocked manner with the second epicyclic gear and third output gear; and

at least one motion section configured to drive in an interlocked manner with a respective output among the plurality of outputs generated from the differential gear assembly, and to apply a respective external resistance among the at least one external resistance to the differential gear assembly.

2. The robot according to claim **1**, wherein the first output gear is provided with sawteeth in its inner circumference, the middle gear is provided inside of and distanced from the first output gear, and the first differential gear set further comprises a plurality of first epicyclic gears configured to engage the inner circumference of the first output gear and an outer circumference of the middle gear at the same time.

3. The robot according to claim **2**,

further comprising a buffering section between each motion section among the at least one motion section and the differential gear assembly, the buffering section configured to adjust a distance between the respective motion section and the differential gear assembly in order to keep the respective motion section contacting a motion surface.

4. The robot according to claim **3**,

further comprising a buffering adjuster interlocked with the buffering section and configured to adjust an initial distance between the respective motion section and the differential gear assembly.

5. The robot according to claim **1**,

wherein at least one of the first output gear, second output gear, and third output gear is provided with sawteeth in its outer circumference, and

the sawteeth provided in an outer circumference of at least one of the first output gear, second output gear, and third output gear drive in an interlocked manner with a respective motion section among the at least one motion section to receive the respective external resistance.

6. The robot according to claim **5**,

further comprising a buffering section between each motion section of the at least one motion section and the differential gear assembly, the buffering section configured to adjust a distance between the respective motion section and the differential gear assembly in order to keep the respective motion section contacting a motion surface.

7. The robot according to claim **6**,

further comprising a buffering adjuster interlocked with the buffering section and configured to adjust an initial distance between the respective motion section and the differential gear assembly.

8. The robot according to claim **1**,

wherein the at least one motion section comprises a first motion section configured to drive in an interlocked manner with the first output gear and apply the first external resistance to the first output gear, a second motion section configured to drive in an interlocked manner with the second output gear and apply the second external resistance to the second output gear, and a third motion section configured to drive in an interlocked manner with the third output gear and receive the third output from the third output gear.

9. The robot according to claim **8**,

wherein the first, second and third motion sections are distanced by 120° from one another around a central axis of the differential gear assembly.

10. The robot according to claim **8**,

wherein at least one of the first motion section, second motion section, and third motion section comprises a pair of motion sections extended from an outer surface of the differential gear assembly and distanced from each another along a longitudinal direction of the differential gear assembly.

11. The robot according to claim **1**,

further comprising a body section mounted to an outer surface of the differential gear assembly to protect the differential gear assembly.

12. The robot according to claim **11**,

further comprising a camera module mounted to a front portion of the body section.

13. The robot according to claim **1**,

further comprising a buffering section between each motion section of the at least one motion section and the differential gear assembly, the buffering section configured to adjust a distance between the respective motion section and the differential gear assembly in order to keep the respective motion section contacting a motion surface.

14. The robot according to claim **13**,

further comprising a buffering adjuster interlocked with the buffering section and configured to adjust an initial distance between the respective motion section and the differential gear assembly.

15. A robot using a multi-output differential gear, the robot comprising:

a driver;

a differential gear assembly configured to receive a driving power from the driver, and to drive in an interlocked manner with the driving power to generate a plurality of outputs differentiated from the driving power, the differential gear assembly comprising:

a first differential gear set configured to receive the driving power from the driver and comprising a first output gear configured to generate a first output among the plurality of outputs having a different rotary speed from the driver when receiving a first external resistance,

a middle gear configured to drive in an interlocked manner with the first output gear to generate a middle output among the plurality of outputs, and

a second differential gear set configured to receive the middle output from the first differential gear set and comprising

a second output gear configured to generate a second output among the plurality of outputs having a different rotary speed from the middle output when receiving a second external resistance, and

a third output gear configured to drive in an interlocked manner with the second output gear to generate a third output among the plurality of outputs having a different rotary speed from the second output;

a first motion section configured to drive in an interlocked manner with the first output gear and apply the first external resistance to the first output gear;

a second motion section configured to drive in an interlocked manner with the second output gear and apply the second external resistance to the second output gear; and

a third motion section configured to drive in an interlocked manner with the third output gear and receive the third output from the third output gear,

wherein the first, second and third motion sections are distanced by 120° from one another around a central axis of the differential gear assembly.

16. A robot using a multi-output differential gear, the robot comprising:

a driver;

a differential gear assembly configured to receive a driving power from the driver, and to drive in an interlocked manner with the driving power to generate a plurality of outputs differentiated from the driving power;

at least one motion section configured to drive in an interlocked manner with a respective output among the plurality of outputs generated from the differential gear assembly, and to apply at least one external resistance to the differential gear assembly;

a body section mounted to an outer surface of the differential gear assembly to protect the differential gear assembly; and

a camera module mounted to a front portion of the body section.

* * * * *